

SECTION II.—GENERAL METEOROLOGY.

PHOTOMICROGRAPHS OF SNOW CRYSTALS, AND
METHODS OF REPRODUCTION.

By WILLIAM A. BENTLEY.

[Dated: Jericho, Vt., August, 1918.]

The writer has noted some recent German criticisms¹ of his photomicrographs of snow crystals, in which he is accused of having in some cases "greatly retouched them," or "mutilated their outlines." Such criticisms seem unfair and unjust, in view of the fact that those making them know, through personal correspondence with the writer or otherwise, that nearly all his original snow-crystal images have been preserved absolutely untouched, and are available for comparison with the copies the writer has cut out in relief for the use of educational institutions and for publication.

Of the 3,000 photomicrographs of snow crystals obtained, absolutely untouched images of at least 2,500 have been preserved. Copies of the earlier specimens were not made for reproduction purposes, and this is also true of a few later specimens of plain outline or of inferior interest. As was to be expected in so large a collection, a few originals have been broken.

The writer feels that his photomicrographs of snow crystals are so well known, and have been so minutely examined and studied both by scientists and the general public, that no statement or argument is needed to preserve their reputation. Certainly no American meteorologist or scientist who is intimately acquainted with them, or who has seen them magnified tens of thousands of times when shown upon the screen, will believe that any of them can be correctly described as "greatly retouched" or "mutilated." The individuals and institutions that have studied the author's methods and his photomicrographs most closely are the most appreciative of the latter and the most enthusiastic in their use.

The writer fully appreciates Dr. Hellmann's eminent services to meteorology and to general knowledge, but he has no sympathy with that perverted or ultrascientific viewpoint that insists on having a photograph presented exactly as it emerges from the chemical bath, with all the false light impressions of dust and other foreign particles glaringly in evidence and falsifying the result. A true scientist wishes above all things to have his photographs "as true to Nature" as possible; and if retouching will help in this respect, then is it fully justified. It occasionally happens in snow-crystal work that dust particles or particles of snow-crystal débris fall upon the faces of the tabular crystals and can not be removed. These foreign particles may cover and hide from view important details, and in any event will mar the beauty and falsify the image of the snow crystal. Hence they should be retouched out as far as available means permits.

A recent English translation of Dr. Hellmann's "System der Hydrometeore"² having again brought the snow crystals to the attention of the readers of the MONTHLY WEATHER REVIEW, the writer feels that a brief statement of his methods, and the difficulties to be overcome in securing natural and true-to-nature photomicrographs

of these exquisite yet evanescent objects, may be timely and of interest.

The chief photomicrographic difficulties may be grouped under the heads of "Transparency," "Evaporation," and "Snow débris."

TRANSPARENCY.

Snow crystals, though often extremely transparent, possess sharp outlines and present a white appearance to the unaided eye, because their numerous facets brilliantly reflect the light. In a photomicrograph, however, the transparency of the main body of the crystal makes it assume the tint of whatever background it may be projected upon, thus rendering it inconspicuous, often lacking in clearness of outline, and unnatural in appearance. There seems, indeed, no purely photographic method of reproducing such crystals clearly and naturally and beautifully. The writer's studies, however, led to an intense love for these marvellous crystals. He felt that a way *must* be found to reproduce them in all their unrivalled beauty, with sharp outlines, white upon a dark ground. It was soon noted that when viewed under a pocket lens their outlines in the negatives were sufficiently well defined to permit their being followed with the point of a penknife. So the "blocking out" method was tried, cutting the film of the negative away from the snow crystal image, and, although exceedingly tedious, it has proved to be an ideal method. All the more beautiful specimens among our 3,000 snow photomicrographs have been treated in this way. The writer feels strongly that whatever microscopic exactness of outline is lost thereby is made up manyfold by the greater naturalness and sharpness of outline and enhanced beauty of the snow crystal images produced by this method.

The whole method is portrayed photographically in photographs No. 890 (A), 890 (B), 2681 (A), and 2681 (B), reproduced on Plate 1. No. 980A is reproduced from a print from the original untouched negative. No. 980B is reproduced from a print from this negative with the film surrounding the snow crystal image removed by the "blocking out" process. No. 2681A is also reproduced from a print from the untouched negative, and No. 2681B is reproduced from a print from this negative with half the film surrounding the snow crystal image removed by the "blocking out" system. It is to be noted that none of the fineness of detail of 890A or 2681A is lost in 890B or 2681B. On the contrary, the details stand out in greater clearness against the black background of 890B, and the left-hand half of 2681B.

However, the importance was early realized of preserving the original images untouched, as proof of the correctness to Nature of the work. This has been accomplished in two ways—(a) the original negatives have been preserved intact by making copy negatives from the originals and cutting the film away on these copies; or (b) a positive copy has been made on glass of the original negative before cutting away from around the image of the snow crystals thereon. The collection now includes about 1,500 original unchanged negatives and about 1,000 copied "positives," taken before the film

¹Hellmann, Gustav. System der Hydrometeore. Berlin, 1915. (Veröffentl. d. K. preuss. Meteorol. Institut. Nr. 285; Abhandlgn. Bd. 5, Nr. 2).

²MONTHLY WEATHER REVIEW, July, 1916, 44: 335-392; and Jan. 1917, 45:12-16.

was cut away from around the snow image. The author's faith in the correctness of his work is shown by the fact that criticism has always been courted, and an effort has been made to have the Weather Bureau or some other institution take over the custody of the original negatives and positives of snow forms.

EVAPORATION.

An almost *ever present* difficulty in securing exact outline images of snow crystals arises from evaporation, and this is especially true of the *branchy* forms. Sometimes a slight wearing away of the crystals by evaporation occurs even before the crystals reach the earth. When they are placed apart on a glass slide evaporation usually proceeds rapidly, and the crystals last but a few minutes, or even seconds in some cases. Their outlines pass quickly through various changes of form, no two of which are alike. Evaporation oftentimes occurs in such a way as to intensify whatever lack of symmetry the mature crystal outline may have possessed. Points or parts that are slightly smaller than their neighbors, and usually also slightly thinner, evaporate the more rapidly. Moreover exterior deformation oftentimes occurs as a result of the grouping of separate crystals. For example, when placed for observation and photomicrographic purposes on a glass slide the outlying parts, or points projecting away from the group or away from a neighboring crystal, always evaporate much the more rapidly. For these reasons photomicrographs always tend to show snow crystals less beautiful and less symmetrical than they actually are in Nature. Doubtless Dr. Hellmann's conclusion that "it is rarely that ideally perfect crystals occur in Nature" is largely due to this fact, for many of the photomicrographs of snow crystals taken for him by Dr. Neuhauss to be used to illustrate his interesting book, "*Schnee Krystalle*,"¹ were deformed and robbed of much of their natural symmetry as a result of their being grouped together for photographic purposes. His plates I, III, and IV show this "deformation" in greatest degree.

Many of the writer's photomicrographs show a similar evaporative deformation, though great pains have been taken to guard against it. The results of this most interesting phenomenon are instructively shown in some of the photographs, and especially in Nos. 389 and 1887, Plate 1, both of which are photographs of crystals which were originally very perfect and symmetrical. It will be noted in these photographs that evaporation is retarded in greatest degree at the points of contact or near approach of one crystal to another, but that some retardation occurs even half way around the circumference of each neighboring crystal, as though some subtle interaction between them tended to retard evaporation. A possible explanation is that the initial evaporation is everywhere at a uniform rate, but the region immediately surrounding the points of near-contact of the crystals becomes more completely saturated than elsewhere, and hence subsequent evaporation therein undergoes a retardation.

That crystals possessing almost perfect symmetry undergo intensified evaporative deformation as a result of one half being slightly smaller and thinner than the opposite half, is interestingly shown in photographs No. 2513A and 2513B, Plate 2, which portray the same crystal. No. 2513B was taken after No. 2513A, and shows intensification of evaporative deformation.

SNOW DÉBRIS.

Oftentimes a given snowfall consists of a mixture of perfect crystals of average size, tiny immature crystals, and small particles of snow *débris*, etc. These latter collect upon and adhere to the perfect crystals and are not easily removed. Photograph No. 2330A, Plate 2, is a case in point. The tiny crystal attached to its face could not be removed. This specimen is simply marvelous as regards perfect symmetry and beauty of interior. Special efforts were therefore made to retouch out the image of the tiny "germ crystal," and with some degree of success, as shown in the second photograph, No. 2330B, Plate 2, cut out in relief. No. 2585A, Plate 2, is another case of this kind. After trying in vain to remove the snow *débris* adhering to the crystal, a photograph was made, followed by a second partially successful attempt at removal, and a second photograph, No. 2585B, Plate 2. But evaporation meanwhile had done its work, and removed many interesting exterior parts and greatly modified the crystal. So once again retouching from the first image was tried, and with what success is shown in the last photograph of the series, No. 2585C, Plate 2, cut out in relief. These last examples doubtless come under Dr. Hellmann's description of being "unfortunately greatly retouched." The verdict as to whether retouching in such cases is justified or not is left to the reader.

CONCLUSION.

From the foregoing it will be seen that we can not always reproduce, even in the photographs, images of the snow crystals that show their outlines exactly as they were when leaving cloudland or alighting upon the earth. Yet a little thought will convince us that this impairs their value or interest but little, as ultimate (mature) outline represents but one (the final) stage in the formation of crystals that usually undergo a multitude of changes of form and outline from time to time as growth progresses from the nuclei outward.

The high regard in which these photomicrographs of snow crystals are held is shown by the fact that almost every university of note in the United States has a set of from one to several hundred for educational uses. The University of Wisconsin alone has 2,000 lantern slides, and Prof. B. W. Snow, who is exceedingly enthusiastic in the use of them, began making purchases in 1889. His lectures on snow crystals have become deservedly famous. The following are quotations from his letters to the writer. Writing in 1910 he says:

President Van Hise has followed your work with the greatest interest, and he has taken an enjoyment in your slides equal to my own, and has expressed himself repeatedly as being thankful that you can do for the world of science the work you are doing, and make so beautiful a contribution to our knowledge of the world of Nature.

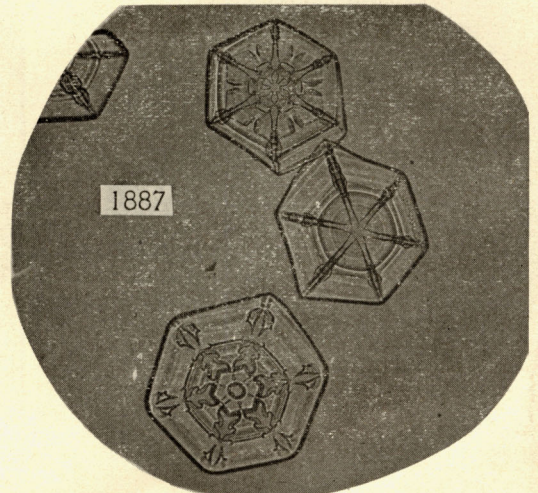
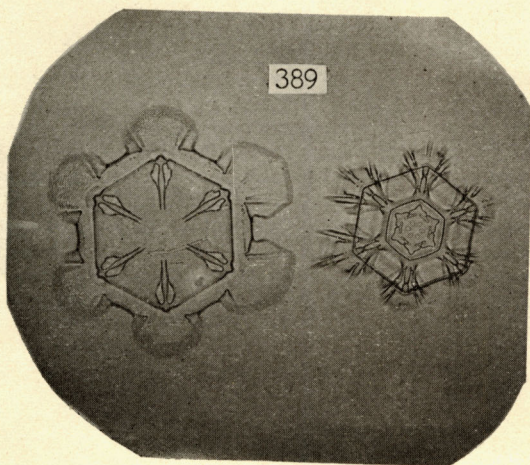
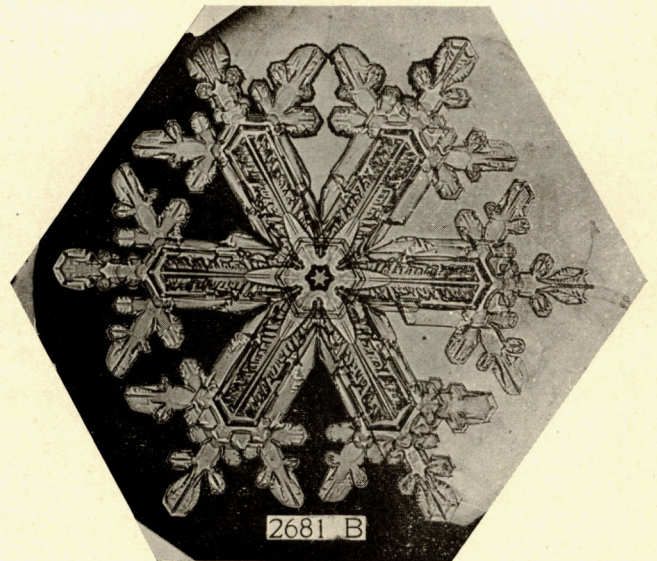
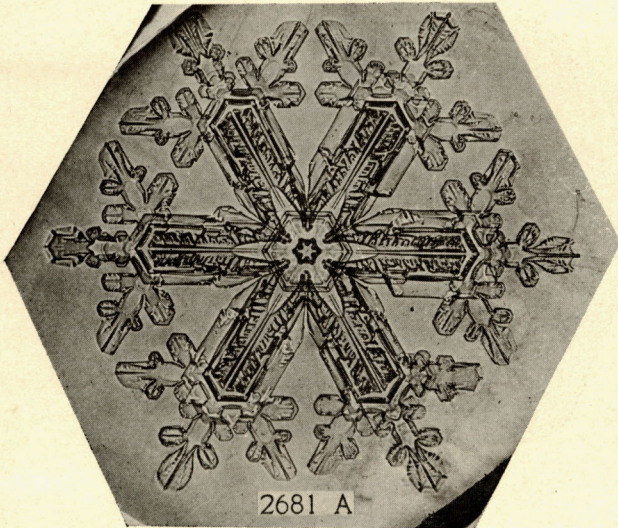
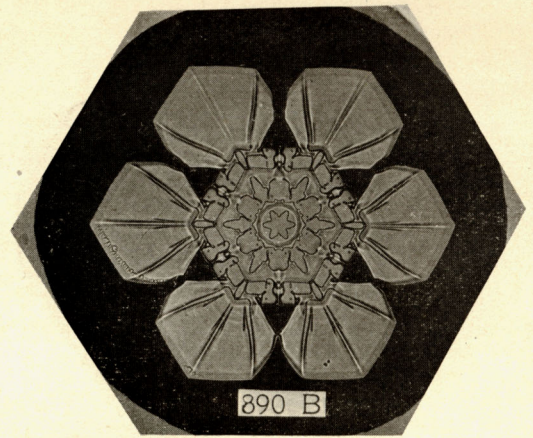
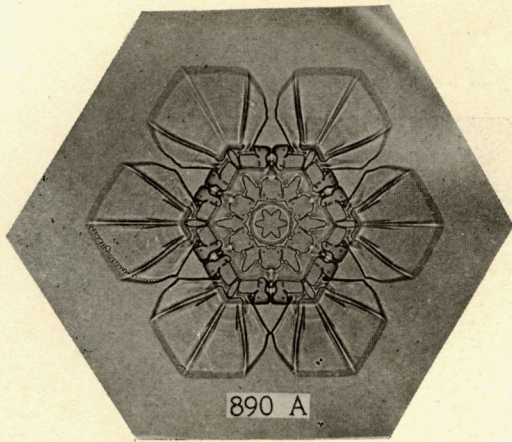
In 1915 he again writes:

You will not be surprised to hear that my own and the interest of my students increases each year, and that there is no one matter which I present during the entire year which brings such pleasure to my classes.

And again, in 1917, after receiving the 178 new photographs of the 1916-17 crop, he writes:

All that I looked at are beautiful and give me the most exquisite pleasure, as they will do over and over again, as I shall see them repeatedly during the coming years. You are doing a great work in enabling students and scientists and people in many other walks of life to see and appreciate the infinity and prodigality as well as the beauty of nature.

¹ Hellmann, Prof. Dr. Gustav., Berlin, 1893.



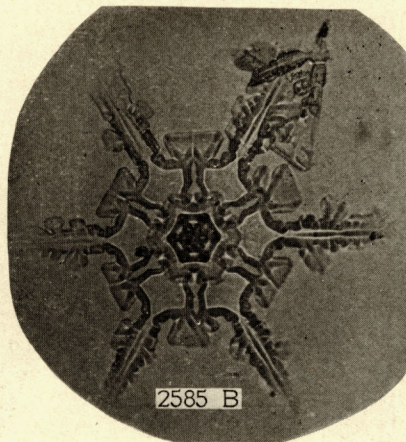
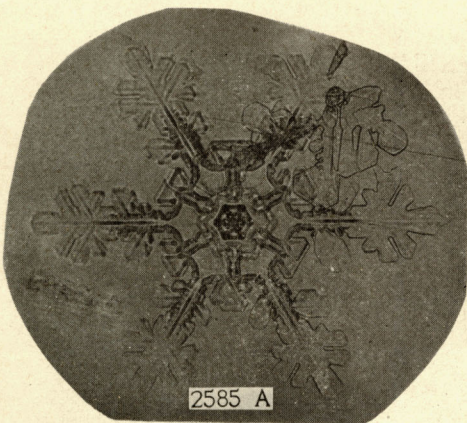
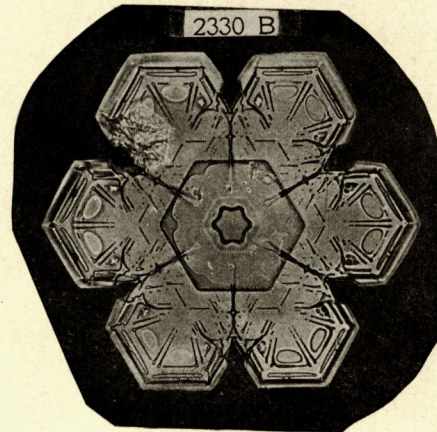
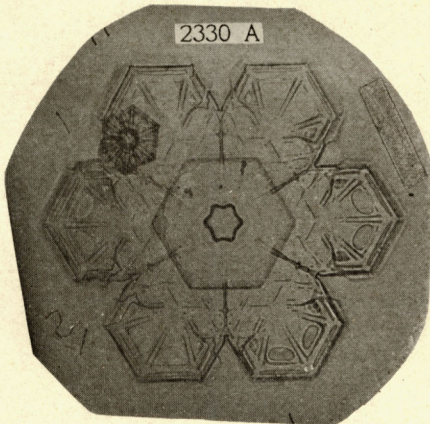
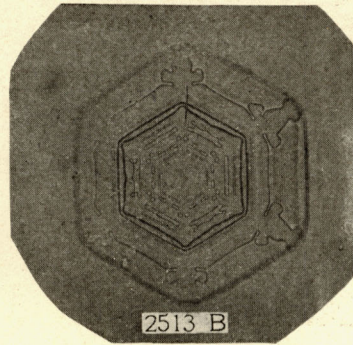
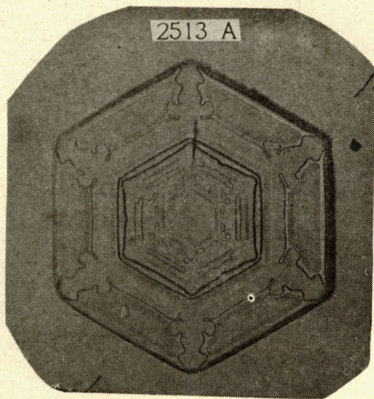


Plate 2.